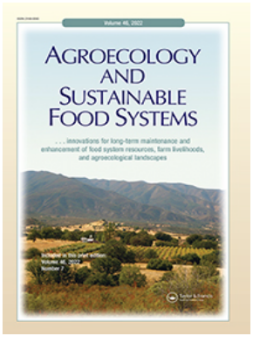

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Organic farmers face persistent barriers to adopting diversification practices in California's Central Coast

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ABSTRACT

In the face of myriad environmental challenges associated with industrial agriculture, some farmers and researchers have looked to diversified farming systems as a promising alternative. Despite well-documented ecological benefits, diversification practices remain rare in many regions of the U.S, even amongst organic farmers. Our study focuses on organic farmers in the Central Coast region of California, an area that has played a crucial role in the rise of organic agriculture over the last several decades. Through 20 interviews with farmers who all grow lettuce and 8 interviews with technical assistance providers, we investigate the persistent barriers that growers in this region face in adopting diversification practices including cover cropping, compost application, crop rotation, insectary strips, and hedgerows. We find that high land rents, the predominance of short-term leases, stringent food safety standards, and other supply chain pressures significantly hamper the adoption of diversification practices. In order to surmount these barriers and increase adoption, solutions must be pursued at three interconnected levels: innovation at the farm level, and policy change at the technical and structural levels. Locally-informed, integrated, and innovative policies across these three levels must be explored to support the creation of a more resilient, sustainable, and equitable food system.

KEYWORDS

Sustainable agriculture; agroecology; agricultural policy; diversified farming systems; farm management; land access; supply chains

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Introduction

In the face of myriad environmental challenges associated with industrial agriculture, some farmers and researchers have looked to biologically diversified farming systems as a promising alternative. By fostering biodiversity both above and below ground, farmers can bolster ecosystem services, which benefit both their crops and the surrounding environment (Kremen and Miles 2012; Tamburini et al. 2020). Farmers can increase functional biodiversity in a number of ways including diversifying the mix of crops they plant, growing soil-building cover crops in the offseason, applying composts that stimulate soil life, and planting hedgerows or insectary strips along the edges of their fields. Belowground, these diversification practices[1] improve soil health, which supports crop growth and buffers against drought and floods (Bowles et al. 2020; Gaudin et al. 2015; Tamburini et al. 2020). Aboveground, diversification practices provide habitat for pollinators, beneficial insects, and other wildlife (Kremen and Miles 2012; Tamburini et al. 2020).

Yet diversification practices remain rare in many regions of the U.S., especially those dominated by agribusiness (US Department of Agriculture, Natural Agricultural Statistics Service 2019; Wallander et al. 2021). In these farm communities, a tight web of social relationships, policies, economic structures, cultural traditions, ecological constraints, and even aesthetic preferences have maintained status-quo agriculture over the past half century, even in the face of major disruptions to global markets and the climate (Carlisle et al. 2019; Philpott 2020). Inflexible supply chain requirements and the need to maximize production from highly valuable agricultural land pose powerful obstacles – these considerations are particularly true in California where agricultural land values are more than three times higher than the national average (Baur 2020; Guthman 2004; National Agricultural Statistics Service 2021). When high land values demand two or more cash crops per year and thus precisely timed field operations, there is little room for error in scheduling. For instance, farmers may be hesitant to use winter cover crops if they perceive risks of delays to spring cash crop planting, especially when they have harvest contracts locked in well before the season starts (DeVincentis et al. 2020), or if cover crops produce high amounts of residue that impedes timely cultivation and crop establishment (Brennan 2017). Meanwhile, in the wake of the 2006 outbreak of pathogenic *E. coli* in spinach, public and private food safety policies have created rippling effects for leafy green growers (Karp et al. 2015). To this day, these policies discourage diversification practices that might harbor wildlife in or near fields, despite lack of evidence of food safety risks emanating from these wildlife or practices (Olimpi et al. 2019).

At the same time, the rise of an alternative agriculture movement in the U.S. has created not only individual diversified farms but also an array of institutions and markets intended to support and value this biodiversity-forward approach to farming. One node of this diversified farming movement is the Central Coast of California, a region that contains both the progressive college town of Santa Cruz (a hub of countercultural thought at least since UC Santa Cruz was founded in 1965) and the fertile farmland of the Salinas Valley. Beginning in the late 1960s, farmers and young people in this region banded together to learn ecological (often indigenous) strategies for raising food, which they branded "organic." They formed one of the first organic certification organizations in the country, California Certified Organic Farmers. They supported the growth of one of the first agroecology programs at a U.S. university, then worked with the researchers there to innovate methods for growing strawberries without chemical pesticides (Reti, Rabkin, and Farmer 2012). Along the way, they developed a strong consumer base for organic food, helping to build up a U.S. organic industry that has experienced such steady year-over-year growth that it now boasts $61.9 billion in annual sales (Organic Trade Association 2021).

In short, if there were a sector of U.S. agriculture where we might expect significant adoption of diversification practices, organic producers in the Central Coast of California would be a promising bet. Yet it is common knowledge among farmers and technical assistance providers that the use of these practices varies widely across organic farms in this area. Indeed, the steady growth of the organic sector has been due in part to conventional farmers recognizing expanding opportunities of the organic sector and applying a more conventional style of organics that is largely specialized (i.e., grows few crops) and that replaces synthetic inputs with organic analogs took root (Buck, Getz, and Guthman 1997; Constance, Choi, and Lara 2015). This reflects the heterogeneity of the organic sector in California in terms of management approaches, philosophies, scale, and markets (Guthman 2000, 2004; Tscharntke et al. 2021). In this study, we sought to understand what persistent barriers prevent organic vegetable farmers from utilizing specific diversification practices in such a seemingly supportive context. Prior research in the Central Coast has documented how key structural factors, especially non-science-based and inflexible food safety standards (Baur 2020), have constrained farmers' management options. A related body of research has demonstrated how high rents, along with the prevalence of short-term leases (Calo and De Master 2016), have created pressure for farmers to maximize production and income in the shortest period possible. We build on this work by focusing on how these and other factors influence organic producers specifically, and how their responses in turn depend on factors like access to resources and degree of integration into

industrial supply chains. Ultimately, our research sheds light on both targeted interventions and more transformational changes that could alleviate these barriers and promote more widespread adoption of diversified farming systems.

Methods

In February 2019, we conducted semi-structured, in-depth interviews with 20 farmers in the California Central Coast region who grow organic lettuce as either their primary cash crop or part of a diverse array of crops. We focused on lettuce because it is the most economically valuable vegetable crop grown in the region (California Department of Food and Agriculture 2021). In 2020, Monterey County, the county with the highest agricultural production value in our focal region, had 78,885 acres under organic crop production, representing a nearly six-fold increase in organic acreage since 2012. Of this organic acreage, nearly 30% (22,356 acres) was in organic lettuce production (County of Monterey Agricultural Comissioner 2018, 2019, 2020). Within our interview sample, farms ranged in size from 4 acres to over 10,000 acres (mean:1935 acres; median: 100 acres) and spanned four counties: Monterey (5 interviews), San Benito (4), Santa Cruz (5), and Santa Clara (1), with 5 additional farmers spanning multiple of these counties.

To recruit study participants, we first conducted a search of the USDA Organic Integrity database, which identified 80 organic farms in these counties that listed organic lettuce as a crop. As far as the author team is aware, this is the most comprehensive database of certified organic growers in the US because it collates certification information from individual organic certifiers. While the database itself does not provide additional information about farm characteristics, from this list, we selected a stratified sample, deliberately chosen to reflect a gradient of both crop diversity and ecological diversity in the surrounding natural habitat. Our sample was also stratified to reflect a diversity of farm scales (*i.e.*, sizes), geographical locations within the study region, and cultural backgrounds/first languages. While a parallel research effort (Esquivel and Carlisle et al., 2021) aimed to understand how these different farming scales and business models might impact adoption of diversification practices, this paper aims to understand factors impacting this diverse sample as a whole. Because we deliberately included farm types that are less common (highly diversified, medium-sized, direct-market), our sample represents a higher than average level of diversification practices. Of the 80 organic farms we identified in the database, we contacted 28 farmers to request their participation in an interview. Of these farmers, 3 declined to participate, 5 did not respond, and 20 agreed to participate and completed an interview.

To complement interviews with growers, in May 2019 we also conducted semi-structured, in-depth interviews with 8 technical assistance providers whose names came up repeatedly in interviews with growers. While this was not a systematically representative sample of technical assistance providers in

the region, interviewing these individuals allowed us to verify and build on what we learned from grower interviews about factors influencing adoption of diversification practices, such as land values, supply chain requirements, and food safety. Because these technical assistance providers spoke from their knowledge of the sector as a whole, they could both generalize across multiple operations and speak candidly about sensitive issues that might not be comfortable topics to investigate in the context of a specific operation. These interviews thus provided an opportunity for us to test hypotheses about trends and relationships that were implied in our grower interviews.

Interview questions posed to both groups (see appendices) focused on diversification practices, crop and non-crop diversity, and how farm-level decisions were shaped by various market and policy factors. We began by asking open-ended questions (e.g., what practices do you currently use to maintain or improve soil health on your farm?), and followed with more specific questions (e.g., could you briefly describe your tillage practices?). Interviews were digitally recorded and transcribed verbatim. We analyzed interview transcripts in NVivo 12, using an iterative coding method following an open, axial, and selective coding procedure (Corbin and Strauss 1990). To identify key factors influencing farmer adoption of diversification practices, data were coded into thematic categories, such as "Land Tenure," "Markets," and "Food Safety."

Results

Key structural factors shaping farmers' decisions about diversification practices

Farmers' decisions about whether to adopt diversification practices, and which ones, hinged on two fundamental structural features of the region's agricultural economy: high land rents and concentrated supply chains (See Table 1). How farmers experienced and responded to these pressures strongly influenced their interest in diversification practices and ability to implement them.

Land tenure and rent

High land rents and the predominance of short-term leases (three years or less) emerged as primary factors limiting long-term investments in soil heath and biologically diversified farming systems. High land rents boxed farmers into growing a limited number of high-return cash crops (primarily lettuce and in some cases strawberries), restricting the degree to which they felt they could afford to rotate other cash crops or incorporate cover crops. One farmer described the challenge of lettuce farming in the Central Coast as hinging on "how can I make that land pay for itself in the fastest time?" Meanwhile, the prevalence of short-term leases meant that farmers often did not feel secure investing in long-term soil health, as they were not sure they would be farming

Table 1. Structural Factors Shaping Diversification Practices.

Theme	# Farmers Discussing (out of 20)	# Technical Assistance (TA) Providers Discussing (out of 8)	Illustrative Quotes (farmers)	Illustrative Quote (TA provider)
High land rents and the predominance of short-term leases limit long-term investments in soil heath and biologically diversified farming systems	11	8	"We do some cover cropping, but it's challenging with our rent structure. Can I tell the landlord, hey, don't charge me this year because I'm going to grow a cover crop?" "If the contract isn't long, it doesn't benefit you to incorporate nutrients into the earth. For example, compost. The compost, you put it down, and according to what we understand, it does not work in the first year, it works in the second year. And if you incorporate a lot of compost and you are not going to be there three, four years out, sometimes it is just money that you are wasting."	"The rental costs along the coasts are high and people don't think they can afford to cover crop as much as they should or rotate as much as they should. It also has to do with leasing. A lot of land is leased, which you probably know the statistics. . . . my sense is if you have a short term lease, you don't really care about building the soil that much."
Food safety standards are discouraging biologically diversified farming systems	11	8	"We used to do quite a bit of composting. But that kind of falls under the same food safety regulations that they – [large wholesale buyers], they won't allow you to use any composting anymore because of the possibility of the *E. coli*." "Yeah. Ideally, we should bring in animals, but it's not something we can do with – not under current regulatory requirements."	"We saw a lot of farmers who were doing a good job with hedgerows and native habitat being told by food safety inspectors that they had to have bare ground bordering their production area. And so there was that initial just reaction for all the lettuce – or all the leafy green growers to do that."
Large wholesale markets/buyers discourage biologically diversified farming systems	7	8	"I would say that the wholesale market does not support being diverse or soil health really because basically, even the organic wholesale market demands perfection and size. Huge size and perfect-looking produce. So that pretty much means you have to be just flooding the crops with fertilizer and spraying organic chemicals."	"I know from my time talking to bigger farmers . . . that cover crops have the potential to delay planting, and the big firms are on really tight planting schedules, right? So that's why they don't do that."

the land long enough to enjoy the benefits. As one farmer put it, "if the contract isn't long, it doesn't benefit you to incorporate nutrients into the earth."

Farmers who owned some of their land or were able to negotiate long-term leases (n = 11/20) were better able to recoup their investment in diversification practices and realize a net benefit. When we asked one grower why they preferred longer land tenure, they explained what had happened when they initially farmed on short leases. "When we started organic, people would watch us farm the land organically, and after 2 or 3 years, they would go outbid us on the land and take it away from us because we had put all the compost and the cover crops into it," the grower explained. "We have to really build up the soil and so we just don't like to build it up for somebody else to come and lease it . . . . we like to have longer leases."

Food safety standards

Conversations with growers and technical assistance providers revealed that the ubiquity of food safety discourse in farmers' daily routines was pushing the agricultural community toward thinking of biodiversity as a hazard and a liability rather than a potential benefit. Nearly 15 years later, farmers still described the 2006 *E. coli* outbreak, linked to Central Coast spinach, as a transformational event for leafy greens farming in the area. Following that deadly outbreak, buyers implemented stringent food safety protocols designed to minimize the risk that wildlife could contaminate crops with foodborne pathogens. As one farmer put it, "We call it BC and AD, before the incident and after the incident . . . it's a big, big change."

In most cases, growers cited third party food safety audits required by their buyers as having the most influence on their practices (n = 11/20), with federal food safety regulations playing a smaller role. For growers reliant on wholesale markets, these audits required by their buyers frequently led them to remove vegetation that might harbor animals, including hedgerows, and habitat enhancements, such as owl boxes. As one grower told us, "what used to be a windbreak is now a hazard. So that's why you see a lot of trees being topped." Some growers we spoke to had completely stopped using compost, which can raise food safety concerns if it is made from manure or other materials of animal origin, with regulations stipulating when it can or cannot be applied relative to harvests. Other growers were simplifying their crop rotations and growing leafy greens in the same interior beds year after year, in order to accommodate rules that forbid them from growing certain crops considered 'high risk,' such as leafy greens, near natural landscapes. These growers also mentioned that fencing had become a top priority for their operation, eating up funds and time that they might otherwise have used for conservation or soil health improvements. Across all farm types, food safety standards strongly

discouraged integration of crops and livestock, in an effort to curb potential for cross-contamination. However, many growers believed adding livestock to their farm could be ecologically beneficial. "Yeah. Ideally, we should bring in animals," one farmer said, "but it's not something we can do with – not under current regulatory requirements."

A number of interviewees (n = 7/20) – large scale growers, small scale growers, and technical assistance providers – expressed the opinion that food safety rules favor larger growers with operational budgets big enough to cover investments in new recordkeeping and infrastructure requirements, which in many cases meant hiring an employee dedicated to managing food safety compliance. "The system and the liability is pushing small growers out," one larger grower told us, "because they can't afford the proper food safety staff, not to mention all the other regulations and reporting for water, nitrates, farm plans." One small grower added that food safety rules might limit the diversity of their crop rotation because of the time and expense associated with safety inspections for each crop.

Many growers expressed the opinion that food safety rules were an overreaction (n = 6/20), and some observed that ever more stringent requirements were being used as a marketing tool by large buyers (n = 3/20). Echoing previous findings regarding food safety conflicts in this region (Olimpi et al. 2019), growers noted that buyers appeared to be competing with each other to establish "best in industry" standards for criteria like distance from cattle or frequency of water testing. As one grower said, "if you have somebody that's doing salad mix and they're trying to satisfy Costco or McDonald's or whoever their customer is, they're saying, 'You've got to be a mile away from an animal feedlot. There's got to be bare dirt and a silt fence [a synthetic fabric barrier, commonly used at construction sites, that provides temporary sediment control].' They have a lot of concerns because they're trying to make it [about] liability or bragging rights." Some growers felt that food safety risks emanated mostly from large-scale packing and distribution practices (n = 3/20), a critique which has been advanced in the literature as well (Baur 2021; DeLind and Howard 2008; Stuart and Worosz 2012), and saw efforts to sanitize farms as misplaced, another long-running concern (Stuart 2008a, 2008b). Some felt that the cost of implementing stringent on-farm food safety protocols was a cost the whole lettuce sector was paying in order to minimize the liability of large-scale bagged and boxed salad producers. As one grower expressed, "food safety wasn't a big issue when product was coming in the head and you washed it in your sink and you prepared it . . . . So I objected to that whole – I think it was a diversion to save the bagged salad guys."

Other supply chain pressures

For larger growers selling into wholesale markets, the demands of their buyers strongly shaped their diversification and soil health practices. Their crop rotations were limited to what their buyers (typically wholesale companies or shippers, which aggregate the products of many farms) were willing and able to market. Meanwhile, strict planting and harvest schedules often limited or discouraged cover cropping and could pressure farmers to damage soil health by working land when it was still too wet. As one wholesale grower explained, "It's really hard to plant cover crops in this type of soil because we finish so late in the year, and then we try to get started so early in the year. You basically have December and January as downtime. So, to plant a cover crop, clean up a cover crop by working it into the soil, and then [prepare] your ground and having it ready to plant is really hard to achieve."

In addition to demanding harvests of sufficient volume that can be delivered precisely on schedule, wholesale buyers also prioritized "huge size and perfect-looking produce," as one grower put it. Thus, a barrier to farm diversification arose through the way these buyers judged the value of food products: they tended to focus narrowly on how uniform, large, visually pleasing, and "on time" the harvested crops were, rather than how they were grown. Since wholesale buyers are removed from the day-to-day farm operation, they tended not to assign value to production practices that were good for the farm environment or the farm operation more broadly *unless* they believed those practices would make the products more profitable or easier to sell in the near term. Although organic certification was intended to explicitly assign value to these environmental benefits, long supply chains frequently whittle down organic standards to the most minimal version that will pass an audit (Feenstra and Hardesty 2016; Fleury et al. 2016; Guthman 2004).

The market forces felt by direct-market growers, however, were substantially different. As we discuss further below, many direct market growers found a synergy between consumer demand for a variety of produce at farmers markets and the practical on-farm advantage of a diverse cropping rotation. "I think that the diversity came in as part supply and demand, and then, part also, that it's an ecological way to do it," one direct market farmer said of his complex rotation, which included dozens of different vegetable crops. However, some direct market growers also experienced a tension between growing crops that fit their rotation and crops that were popular and profitable (like strawberries).

Specific pressures shaping adoption of particular practices

In addition to frequently referencing the structural pressures mentioned above, the farmers we interviewed also described several ways in which these structural pressures constrain their adoption of particular diversification practices. Some diversification practices were mainly limited by supply chain pressures, others by land rent and tenure, and others by a combination of factors.

Cover crops

While growers generally believed cover crops would improve the health of their soil, they cited numerous factors limiting their use of them. The main obstacle to cover cropping cited by growers was the cost of sacrificing ground that could be growing a cash crop. "Can I tell the landlord, hey, don't charge me this year because I'm going to grow a cover crop?" one grower expressed. As reported by DeVincentis (2020), we found that growers often had a winter window to plant a cover crop but were concerned about whether they could successfully terminate the cover crop without disrupting their spring planting schedule.

Growers raising baby leaf products (immature leafy greens which are mechanically harvested) mentioned that cover crop residue can be picked up as "foreign material" by harvest machines that cut the crop very close to the soil and have little means to separate chaff from the desired baby greens. Because the presence of "foreign materials" (anything other than the target crop) can result in the rejection of an entire harvest batch, these growers are discouraged from cover cropping and planting rotation crops with significant residue, such as broccoli or cauliflower. Having adequate water (particularly for summer cover crops) was a concern for some growers, and one grower mentioned that labor shortage prevented them from getting a cover crop in the previous winter.

Growers also described ways they circumvented these challenges. For instance, in order to reduce the time required for bed preparation during a transition from a cash crop to a cover crop, several growers described growing cover crops on top of vegetable beds rather than after discing the beds down, which is standard practice. As one grower describes, "We are now looking at it so we can transition from a regular crop to a cover crop, maintain our existing beds, and then plant a cover crop right on top of the beds. Something that we can germinate with drip tape. Something we can cultivate. Clean the weeds around it if we're concerned about some other weeds." Growing cover crops on prepared vegetable beds can also help dry soil faster during the spring, allowing soil preparation for cash crops to begin earlier. Others have identified planting windows outside of the wintertime for cover crops, planting fast-growing summer cover crops that can provide important sources of plant biomass to help support soil health (since vegetable crops

often have very little crop residue) or to provide floral resources for pollinators. As one grower told us, "we used to cover crop even during summer with Sudan grass or buckwheat and that's something we might go back to as well with a permanent bed system, where if there's an area that we're not using, we can get a quick cover crop in right on bed tops."

Compost

Using compost was somewhat more widely adopted than cover cropping, as it was relatively easy for growers to incorporate without changing their farming practices. Due to regulatory requirements and the time required to make compost, most growers were buying it, and cost proved a barrier for many smaller growers. For small growers, it was often challenging to find a large enough piece of land that was in between crops to make it worth bringing a truck out to spread compost. For larger scale growers, consistent with previous findings (Olimpi et al. 2019), the main barrier to using animal-based compost was food safety concerns from their buyers, which led some growers to instead fertilize with amendments perceived as less risky, such as heat-treated poultry litter pellets. As one grower said, "we used to do quite a bit of composting. But that kind of falls under the same food safety regulations that they – [large wholesale buyers], they won't allow you to use any composting anymore because of the possibility of the *E. coli*."

Crop rotation

Small-scale and mid-scale farms were more likely to grow double-digit numbers of different crops in rotation with one another, due to more flexible markets which frequently rewarded a broad crop portfolio. Farmers described long crop lists as an advantage in marketing to regional grocery stores or farmers' market customers, who gravitated toward displays with a wide array of produce, where they could make a one-stop shop. As one grower said, "when you're marketing the way that we do, to have a diversity of crops to market is a big benefit . . . . If you really wanted to look at tapping into some of the local markets, like stores, if you have a price list that you can send out with 20 items it's much easier for a store to make an order as opposed to having a price list with 4 or 5 items." However, some farmers had trouble finding sufficient information or technical assistance to support them in growing less common crops (n = 5/20), and some expressed that they did not have enough space to rotate through all the crops they would like to grow (n = 3/20).

While all the large-scale growers interviewed (n = 8/20, those managing >500 acres) expressed the importance of crop rotation for suppressing disease and building soil health, most were locked into wholesale markets for a limited number of crops. Technical assistance providers working with these growers stressed the importance of developing more robust and profitable wholesale markets for crops to rotate with lettuce. Broccoli, for example, can prevent the

buildup of soilborne pathogens and provide many of the benefits of a cover crop, but research suggests that many farmers on the Central Coast currently grow it at a net loss (Tourte et al. 2017).

Insectary strips

In general, we found that there were few barriers to adopting herbaceous flowering plants as beneficial insect habitat, with 17 of the 20 farmers that we interviewed engaging in the practice. These "insectary strips" could be planted quickly in whatever space the farmer had available, without disrupting cash crops. Because these fast-growing annual plants could mature, flower, and begin attracting insects within the same timeframe as the crops themselves, they could be inserted and removed quickly, in concordance with the demands of strict planting schedules and short leases. Alyssum was widely planted by growers at all scales and perceived as a good way to attract beneficial insects, particularly for controlling aphids. Many growers were also letting cilantro, dill, or fennel mature until they flowered, also to attract beneficials. Still, some smaller growers limited their use of insectary strips, citing space constraints or training and information barriers.

Hedgerows

Hedgerows were notably less common than herbaceous non-crop vegetation: just 8 of the 20 farmers in our sample population were utilizing them at all, and only about half of these plantings were large enough for the farmers to notice any benefits to their farming operation. Unlike insectary strips, hedgerows are perennial plantings that require 7–16 years to mature sufficiently to provide pest control and pollination services equivalent to the cost of the initial investment (Long, Garbach, and Morandin 2017). Hence, the only farmers in our study who were able to invest in them were those with long-term land tenure, mostly landowners. Those farmers who had established hedgerows robust enough to provide noticeable pest management and erosion control described a process that evolved over many years, as they added additional plantings with support from federal and state conservation programs. Farmers with more stable land tenure had a greater ability to tap into publicly-funded conservation programs to offset upfront costs associated with planting and expanding hedgerows.

The majority of farmers we interviewed, however, had deliberately chosen not to incorporate hedgerows. Growers selling into wholesale markets cited food safety concerns from their buyers, which had prompted them to remove hedgerows or avoid planting them in the first place. One of these larger growers was very explicit about this reason for adopting herbaceous flowering plants rather than hedgerows, saying, "we've removed any hedgerows or anything because of the food safety issue. What we use now is we'll plant alyssum or a cilantro or even a celery sometimes in with a romaine crop or a broccoli or

a cauliflower and use those as beneficial rows." Although smaller growers with direct markets faced fewer food safety-related pressures, they seldom had sufficient resources to front the cost of hedgerows, or long-enough leases to ensure that they could recoup the benefits of investing in a hedgerow.

Discussion: increasing adoption of diversification practices on California's Central Coast

Barriers to diversification on the central coast

Our research with organic vegetable farmers on California's Central Coast demonstrates the remarkable persistence of familiar obstacles, even as the sector has experienced significant changes over the past two decades. Dating back at least as far as Guthman's classic studies of the then-emerging California organic sector (2000, 2004), social scientists working in this and comparable regions consistently cite the fundamental barriers we note in our results, such as uncertain land tenure and high rents (Soule, Tegene, and Wiebe 2000) and market values that fail to cover the full cost of diversified production. For instance, rents in Monterey and Santa Cruz counties, where our study took place, can range from US$850 – $3800 per acre for vegetable row crops and average $2900 per acre for romaine lettuce hearts (Tourte et al. 2019). Farmers operating on rented land with short leases may not feel that it is worth investing in soil conservation practices and diversified crop production, practices which generally accumulate benefits relatively slowly over time (Chapman et al., 2022).

Other barriers have grown stronger since early studies of California's organic sector, namely stringent and inflexible food safety standards (Baur 2020). The detrimental impacts of food safety pressures on farm biodiversity in the California Central Coast are well documented (Beretti and Stuart 2008; Lowell, Langholz, and Stuart 2010; Olimpi et al. 2019). While direct market growers experienced fewer of these pressures, they often managed small-scale operations, so food safety requirements represented outsized capital expenditures. Previous research has shown that direct food safety costs such as audit fees do not scale, such that small farms pay proportionately more to comply than do large farms (Adalja and Lichtenberg 2018; Astill et al. 2018; Bovay, Ferrier, and Zhen 2018). Our interviews highlight that the indirect costs of food safety compliance–such as limiting the number of crops grown by diversified operations and the growing pressures to create 'sanitized' farms – likely exacerbate this difference.

Even as the organic market has grown dramatically – with extensive support from hundreds of nonprofit organizations and social enterprises dedicated to expanding organic and/or biologically diversified farming – these fundamental,

structural barriers of expensive land, short-term leases, and industrial supply chains continue to limit the degree to which growers are able to utilize these strategies and realize their many benefits.

In our research, we observed the specific ways in which these structural barriers impact particular diversification practices, explaining why farmers may adopt some practices but not others, and why existing incentives are often insufficient to address the full risk and cost of adopting a practice. In many cases, it was neither a lack of perceived benefits nor the direct cost of adopting a practice (e.g., purchasing cover crop seed) that dissuaded farmers, but rather the indirect costs or risks associated with structural factors (e.g. rigid planting and harvesting schedules imposed by buyers). Indeed, many farmers we interviewed had previously incorporated practices such as using compost or planting hedgerows but stopped using them due to the structural pressures of an increasingly industrialized supply chain. The decision-making process for farmers considering adoption is thus far more complex than simply tallying up expected costs and returns for the farm bottom line.

How then might these barriers to diversification practices be addressed, such that researchers twenty years from now will not reproduce these very same results? We suggest three complementary approaches at the farm level, technical policy level, and structural policy level, which we view not so much as discrete stages of change but as an overlapping continuum with many interconnections. Movement along this continuum contests structural barriers in increasingly fundamental ways, such that these barriers could have progressively less power to shape farmers' decisions, and ultimately no longer exert such a dominant influence over the landscape and sector as a whole.

Farm level: navigating, circumventing, and contesting structural barriers

As we discussed above, farmers themselves are continuously innovating new ways of navigating, circumventing, and contesting structural barriers to diversification practices. Where these strategies hinge on technical considerations, farmers frequently team up with researchers and technical assistance providers, designing new approaches that allow them to meet their agroecological goals in creative ways. For example, as noted above, some farmers in our study area grow cash crops on top of semi-permanent vegetable beds or raise short summer cover crops. Local researchers have also proposed creative ways of addressing issues like foreign material cover crop residue being harvested with baby greens and other challenges of residue from high biomass cover crops. By using a forage harvester, cover crops could actually be harvested and used as a feedstock for producing soluble fertilizer and compost (Brennan 2017). Facilitating knowledge sharing among farmers and researchers could help spread innovative approaches such as these.

Several growers and local cooperative extension agents also noted that overwintering cash crops, like broccoli, supply some of the same ecosystem services that cover crops provide, like scavenging of excess nitrate, while also contributing a potential revenue stream for farmers. Research to quantify these benefits could support wider recognition of overwintering crops as alternatives to cover crops, which in turn could help unlock private and public incentives. For instance, government food purchasing programs could simultaneously increase access to healthy cool season vegetables while also improving the ecosystem services from winter crop cover. The 2008 Farm Bill's Geographic Preference option, which incentivizes the purchase of unprocessed local produce, could be expanded to encourage purchases of winter crops with soil health benefits like broccoli and cauliflower (a "Winter Crop Preference," for example; USDA: Food and Nutrition Service 2011).

Farm-level innovation is one key to overcoming structural barriers to diversification practices. Indeed, farmers' own ingenuity and initiative is clearly responsible for most of the diversification practices we did observe in our study, constituting a critical body of knowledge and experience on which others can build. Researchers and technical assistance providers can help amplify and support these solutions, as can programs that facilitate farmer-to-farmer knowledge sharing. However, as our discussion of overwintering crops demonstrates, such solutions have limited ability to scale out on their own. Scaling up in this way puts too much burden on individual farmers, who typically bear the brunt of up-front costs for long-term, communally shared benefits. Farmers with fewer resources, whether those be economic, social capital, land tenure or inherited wealth, also have far less ability to experiment with and adopt various diversification practices (Esquivel & Carlisle et al., 2021). While some diversification practices can provide a substantial return on investment to farmers over the medium to long term (e.g., soil fertility and pest control), other benefits of these practices are realized at larger spatial scales, providing ecosystem services such as water quality to surrounding communities rather than accruing directly to the practicing farmer (Kremen 2020; Zhang et al. 2007). The interests of individual farmers can diverge from broader society when the benefits of diversification practices emerge primarily for the regional or global community, such as in the case of climate change mitigation (Hillis et al. 2018; Stoate et al. 2001). This divergence between individual and collective interests poses a higher order barrier to adoption that must be addressed through public policy to realign incentives. Hence, the next stage along this continuum must match these public benefits of diversification practices with public support and investments.

Technical policy level: renegotiating the relationship between diversification practices and structural barriers

By building on farmers' own strategies, carefully designed policies can renegotiate the relationship between diversification practices and the structural barriers that hinder them. Our interviews show how many growers struggle with stringent food safety requirements imposed by private wholesale buyers. In particular, industry and supply chain demands that exceed federal public standards around food safety may severely inhibit greater adoption of diversification practices. The challenge with food safety requirements is particularly acute for leafy greens growers who may be at higher risk as their crop is generally consumed uncooked, and who have long been under increased scrutiny and regulatory requirements due to recurrent foodborne illness outbreaks linked to leafy greens in California (Marshall et al., 2021; Olimpi et al. 2019; Turner et al. 2019). While a few growers are able to navigate these requirements without sacrificing their preferred management strategies, most growers feel that they must make trade-offs between adopting diversification practices and compliance with food safety protocols to retain their buyers. Even when buyer demands do not explicitly exceed federal standards, in practice, many growers may feel an implicit pressure to go above and beyond base requirements to demonstrate their due diligence in minimizing perceived food safety risks (Olimpi et al. 2019). Much of this pressure to "do more" is driven by fear and a desire to avoid liability in the case that a food safety issue does arise (Baur, Getz, and Sowerwine 2017). So long as farmers face the threat of catastrophic financial and legal repercussions even when they have complied with food safety standards, they will have a strong incentive to "do more." Such open-ended pressure – where enough is never enough, as risk can never be zero – can and will continue to override farmers' own commitment to promoting on-farm biodiversity through practices such as hedgerows or compost application (Baur 2020).

As such, one strategy to better incentivize diversification practices (or perhaps to mitigate the constraints imposed by private food safety requirements) may be to pass laws that limit farmer liability, both civil and criminal, for growers who comply with basic preventive best practices. Efforts can also be made to increase access to liability insurance. Steps to limit farmer liability would help mitigate the fear that a farmer might go bankrupt from a lawsuit due to a food safety issue. At the same time, industry and regulators must contend with the ongoing liabilities of the pre-washed bagged and boxed salad mix model. Further innovation is needed to refine this manufacturing and marketing scheme, which has wrought the unintended consequence of increased food safety risk to consumers and created a diversification disincentive for producers.

For many small and mid-sized growers, required food safety mitigation and documentation requires such a large share of their time and resources that other priorities like diversification practices may get crowded out. Thus, another potential policy solution may be to offer scale-based subsidies for adopting food safety practices, which would allow smaller growers to hire staff or purchase equipment without draining budgets that might otherwise support diversification (Olimpi et al. 2019). The key to any such policy, however, will be to ensure that the food safety practices being subsidized are science-based and not unnecessarily damaging to biodiversity.

Expansion of existing cooperative certification programs such as the USDA's GroupGAP, which allows for farmers to pool resources to achieve Good Agricultural Practices (GAP) certification, would help growers both defray the costs of food safety compliance and access stable retail and institutional markets that require such compliance (USDA, 2016). Expanding GroupGAP may also support the creation of a federal 'gold' standard that could provide a clearer set of evidence-based best-practices and supplant the private standards that limit management options for many growers. While the Food Safety Modernization Act mandate to the FDA to create the Produce Safety Rule was supposed to build the reputation of public standards such that they are universally recognized and accepted (Food and Drug Administration 2021), the proliferation of private food safety standards makes evident that this goal has not yet been accomplished. This effort could further be supported with increased funding for research on the impacts of farming practices on pathogen-suppression and mitigation (e.g., pathogen-suppressive soil microbial communities; Samaddar et al. 2021).

One hopeful example of how policy might be tweaked to better incentivize diversification practices involves local water quality regulations. In California, regional water boards develop regulatory approaches for meeting water quality objectives, setting standards for growers that in theory take into account local input and needs (Drevno 2016, 2018; Harter 2015). In the Central Coast, The Central Coast Regional Water Quality Control Board focuses primarily on mitigating nitrate pollution of groundwater, and requirements have historically focused on balancing nitrogen fertilizer inputs with nitrogen exports in crops. However, this approach has failed to recognize the potential benefits of diversification practices for achieving water quality outcomes (e.g., scavenging nitrate by winter cover crops; Wyland et al. 1996) while also creating challenges for growers using organic amendments. Much of the nitrogen in organic amendments is not immediately available for crop uptake, requiring microbially-mediated transformations to become available to plants and in forms that are susceptible to harmful losses. Depending on the type of amendment, the majority of the nitrogen might become available after just a couple of months, or it may take years. Yet regulations initially required growers to count all the nitrogen in these amendments for the purposes of calculating the

nitrogen balance – treating them the same as synthetic fertilizers – so it appeared as if organic growers were applying much more nitrogen than crops needed. In other words, the regulatory mechanism did not reflect the distinct dynamics of nitrogen from organic amendments, in terms of its availability to crops and susceptibility to loss.

Recently, the Central Coast Regional Water Quality Control Board updated its regulation, spurring a public comment period for the new rule (known as Ag Order 4.0). In response, a coalition of stakeholders (including local technical assistance providers, environmental NGOs, and growers) proposed a new approach to account for organic nitrogen (Brennan 2021). The regulation now accounts for the lower availability of organic nitrogen sources by allowing for an "organic fertilizer discount factor" used to represent the amount of nitrogen mineralized during the first 12 weeks in the year it was applied. Growers can now also receive a "nitrogen scavenging credit" from certain cover crops (only non-legumes with C:N ratio ≥ 20:1 and a minimum biomass of 4500 lbs./acre) that in effect makes cover cropping an attractive way to scavenge and recycle nitrogen, thus making it available for future crops. This discount factor and N-scavenging credit will become increasingly important as regulations ratchet down the amount of nitrogen that can be applied.

As these examples demonstrate, policies that have hindered diversification practices did not necessarily do so intentionally but instead failed to account for unintended consequences. In part, this outcome reflects a failure to engage a more diverse range of voices at the table when policies were developed. By actively soliciting input from a wide range of farmers, frontline communities, scientists, and other stakeholders, policymakers can reform these regulatory frameworks to ensure that the "fine print" through which state environmental and conservation laws are implemented will help rather than hinder the adoption of diversification practices, and the environmental benefits they can provide.

In order to create policies that better incentivize the adoption of biological diversification practices, it is also important to consider that growers in the Central Coast region represent a diverse range of farming and business models (Esquivel & Carlisle et al., 2021). In our sample, we have a range from smaller growers who primarily sell direct to consumer, to larger wholesale growers who sell to national and international markets. These represent fundamentally different business models, and any single policy or incentive program is unlikely to drive changes across this broad spectrum. To more successfully incentivize adoption of diversification practices, policymakers must address the unique barriers that different types of growers face. For example, food safety standards are a particularly acute barrier for larger growers who depend on wholesale distributors to sell their produce, as discussed earlier in this

section. Meanwhile, smaller-scale growers may be more limited by time, labor, or financial resources, and incentives should aim at alleviating the financial burden associated with the adoption of any new practice.

Structural policy level: dismantling structural barriers

Yet to achieve a future in which diversification practices and their associated benefits are widespread on California's Central Coast, we must not only help growers navigate, circumvent, contest, or renegotiate relationships with structural barriers – we must dismantle these structural barriers themselves. One of the most challenging structural barriers to diversification practices in this region is the difficulty and high cost of achieving secure access to land. So long as the market decides the "highest and best use" of this land, farmers' ability to plant cover crops and hedgerows stands little chance given current intensive production of lettuce and strawberries in this region.

One approach for alleviating this structural barrier is to pass legislation at the state level that limits private equity investment and financialization of farmland, a trend which recent research shows has complicated sustainable governance over resources such as groundwater in other intensive agricultural regions of California (Fairbairn et al. 2021). Another approach, proposed as part of the Justice for Black Farmers Act introduced by Senator Cory Booker (D-NJ), would be to create an Equitable Land Service within the USDA, which would acquire land (e.g., from retiring farmers) and make land grants to existing and aspiring farmers of color. In California, a recently proposed bond measure contains funding for a similar effort, which would provide $125 million to the state's Department of Conservation "to improve land access and tenure for socially disadvantaged farmers or ranchers, beginning farmers and ranchers, and farmers and ranchers located in disadvantaged communities, including the acquisition of agricultural lands for the purposes of selling or leasing the acquired agricultural land to socially disadvantaged farmers or ranchers, beginning farmers and ranchers, and farmers and ranchers located in disadvantaged communities" (Equitable Economic Recovery, Healthy Food Access, Climate Resilient Farms, and Worker Protection Bond Act of 2022., 2021). Grassroots organizations such as Agrarian Commons and Minnow are already mobilizing to acquire land, remove it from the speculative market, and create cooperative structures for diversified production in California. Much can also be learned from the Scottish Land Reform Acts, which create new powers, such as community rights to buy, to increase local and communal land ownership (Calo et al. 2021; McCarthy 2020; Ross 2019). A short-term solution available in the 2023 Farm Bill could be incentivizing longer-term leases by including this as a favorable review criterion for application to NRCS programs or offering additional

financial incentives for longer leases. This provision could increase land security and integrate the aims of USDA conservation, farm support, and risk management programs, rather than having them work in opposition to each other.

Market forces, which bundle together the price paid to farmers with the influence of supply chain management pressures, also play a significant role in shaping farm management practices (Baur 2020). In some cases, market forces may incentivize diversification practices, through price premiums associated with voluntary certifications such as the National Organic Program. However, as we heard from the farmers we interviewed, market forces can also discourage diversification practices (e.g., through buyer food safety requirements). When considering opportunities to reduce structural barriers, it is necessary to address prices and supply chain management separately while recognizing their inherent entanglement.

Dominant market prices generally do not reflect externalities of simplified agriculture that emit huge amounts of greenhouse gases and degrade biodiversity, water quality, and soil health. Viewed from another angle, the market's single-minded focus on provisioning services (e.g., yield) and agnosticism toward non-market ecosystem services gives rise to such externalities. Given this baseline split in valuation, crop prices will continue to pose a barrier for individual-level adoption so long as farmers who pay the extra costs of using diversification practices (that tend to reduce environmental externalities) must compete on a level playing field with farmers who do not (and continue externalizing environmental degradation). To mitigate this barrier requires some combination of raising market prices to incorporate the added production costs (in time, money, or land) of diversification practices and internalizing the costs of environmental degradation from conventional simplified agriculture. While the former strategy of raising market prices has mostly been pursued through voluntary certification schemes, such as organic certification, it is also possible to imagine policies that subsidize revenues for farmers that use diversification practices, expanding on pilots such as the Healthy Soils Program (California Department of Food & Agriculture 2021). Likewise, while the latter strategy of internalizing externalities has mostly been pursued through environmental regulations, such as the Ag Order for water quality, it is possible to imagine other policy levers such as a tax or fee on synthetic fertilizers (although California currently levies a fee on pesticides, it is not large enough to significantly impact their use) (Department of Pesticide Regulation 2021; Harter and Lund 2012). The full suite of available policy mechanisms that can govern market prices should be considered in concert as constituent parts of a comprehensive strategy to shift agriculture toward a more sustainable pathway.

Currently, supply chains are structured in such a way as to discourage, rather than prioritize, diversification practices at the farm level. In the Central Coast, farmers are heavily influenced by the demands of their buyers, who

comprise packers, shippers, processors, and the (multi)national foodservice or supermarket retailers they supply. The influence of these buyers' values and priorities on farming practices extends beyond the price point for vegetables. Through practices of supply chain management, buyers can impose requirements for the volume, timeliness, uniformity, aesthetic quality, and safety of farm products. Such requirements generally operate as minimum preconditions for participating in a given market. Notably, these preconditions focus on production practices that are likely to affect the end product (e.g., pest control practices to preserve aesthetic appeal) to the exclusion of production practices that benefit the farm environment or the farm operation. While it may be unrealistic to impose a top-down change in the incentive structure for the entire supply chain, it is possible to imagine policy interventions that could temper the outsized influence that buyers wield over the farmers who supply them. In particular, buyer control results from an oligopsonistic market structure in which relatively many farmers must sell to relatively few buyers, placing farmers at a bargaining disadvantage. Policy interventions that push back against market consolidation and that open up additional marketing channels – for example through the promotion of community food webs (Meter 2021) or investment in local or regional food hubs – could lessen the pressures of supply chain management and thus indirectly lower the barrier these pose to adoption of diversification practices. While President Biden issued an Executive Order on Promoting Competition in the American Economy on July 9, 2021 and required all federal agencies to provide a plan on their actions to address market consolidation, the USDA plan focuses almost entirely on the livestock industry and does not address related issues in vegetable production and sales (Executive Order on Promoting Competition in the American Economy 2021). One promising avenue has been the proliferation of farm-to-institution programs that leverage the purchasing power of hospitals, school districts, and other large institutions to support local small-scale farms (Lo and Delwiche 2016; Thottathil and Goger 2019). Such arrangements can provide an important bridge for building community and regional markets that can provide an alternative venue to multinational supply chains.

While we anticipate that structural questions related to land and supply chains will remain key factors in determining the viability of diversification practices in this region, we encourage researchers and policymakers to investigate the emergence of other structural factors that may prove equally important over time. Even as we were completing our interviews, California was in the midst of implementing new minimum wage and overtime laws, and immigration policy was impacting labor markets as well. The COVID-19 pandemic has added yet another layer to these dynamic shifts in labor conditions and availability, which could ultimately prove to be key determining factors in farmers' ability to implement diversified farming systems – or indeed,

to farm at all. At the same time, policies governing water access are under renewed scrutiny, and these water policies too may become a key structural factor shaping agriculture in California. Currently, the Central Coast has three groundwater basins that are critically overdrafted and climate change will undoubtedly continue to reshape water availability and the politics of water use in the arid West, with farmers facing growing water access challenges (Arax 2020). Lastly, the current situation in the Central Coast largely puts the onus on individual farmers to shoulder the time and resources required to implement diversification practices. While some of these practices may benefit the farm's bottom line, many of the most important ecosystem services generated by such practices provide public benefits to communities beyond the farm. This disconnect between individual costs and distributed benefits imposes a particularly challenging collective action problem that requires more specific study and redistributive public policies to ameliorate (Kremen and Merenlender 2018).

Conclusions

Given the multitude of barriers that farmers face in adopting diversification practices – even on organically certified farms in a region with a strong alternative agriculture movement – our study suggests the need for an integrative three-pronged approach that builds on farm-level innovations to reshape both technical and structural policies. While locally specific farm-level adaptations and technical policies play a key role in addressing immediate concerns (e.g., reducing nitrate pollution), they are most effective when connected to a broader strategy to address structural factors. Hence, voluntary programs and regulatory frameworks should be designed both to incentivize adoption in the near-term and to create openings for the restructuring of broader socio-political and economic structures that limit adoption of conservation practices. The results presented herein reflect the situation of organic lettuce growers in the Central Coast. The applicability of our proposed three-prong strategy should be further examined in agricultural systems across the USA. Given the mounting environmental and economic challenges farmers face, we cannot choose between incremental and structural change: we must do both.

Note

1. We use the term diversification practices throughout this paper, as defined by Kremen et al. 2012. Other systems also emphasize these same practices, such as soil health management, agroecological management, regenerative agriculture, conservation agriculture, or sustainable agriculture.

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Ethics statement

The studies involving human participants were reviewed and approved by the Committee for Protection of Human Subjects. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

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